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US 4466706

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(54) Liquid or semi-solid lens or mirror with system for adjusting focal length

(57) An adjustable liquid lens or mirror comprising a chamber 10 delimited by a flexible membrane surface 1, 6, a first fluid medium filling the chamber which, in the case of a lens, has a different refractive index from that of a second fluid medium contacting the other side of the flexible membrane, and an annular support member 2 for the flexible membrane comprising relatively movable first 3 and second 7 component parts, the first and second component parts of the support member being adjustably linked in a fluid-tight manner, via 12, whereby the volume of the chamber 10 is adjustable by moving one component part of the support member relative to the other in such wise as to vary the pressure in the first fluid medium and thereby to alter the shape of the said membrane surface 1, 6.

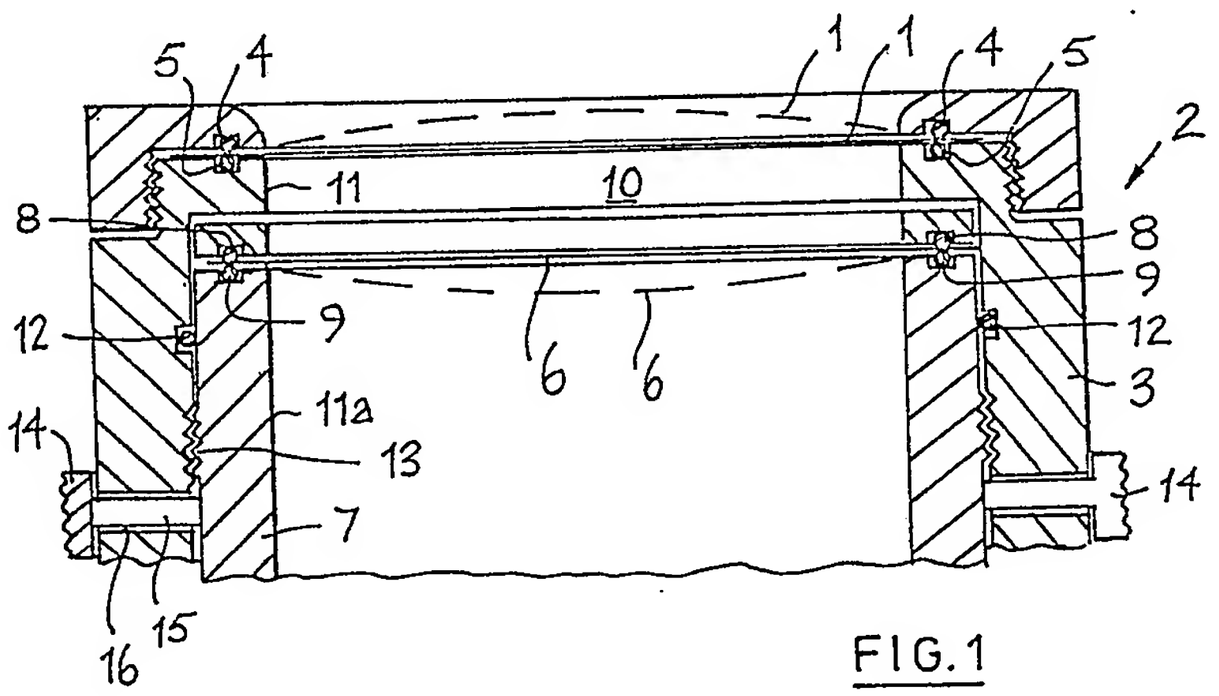

FIG.1

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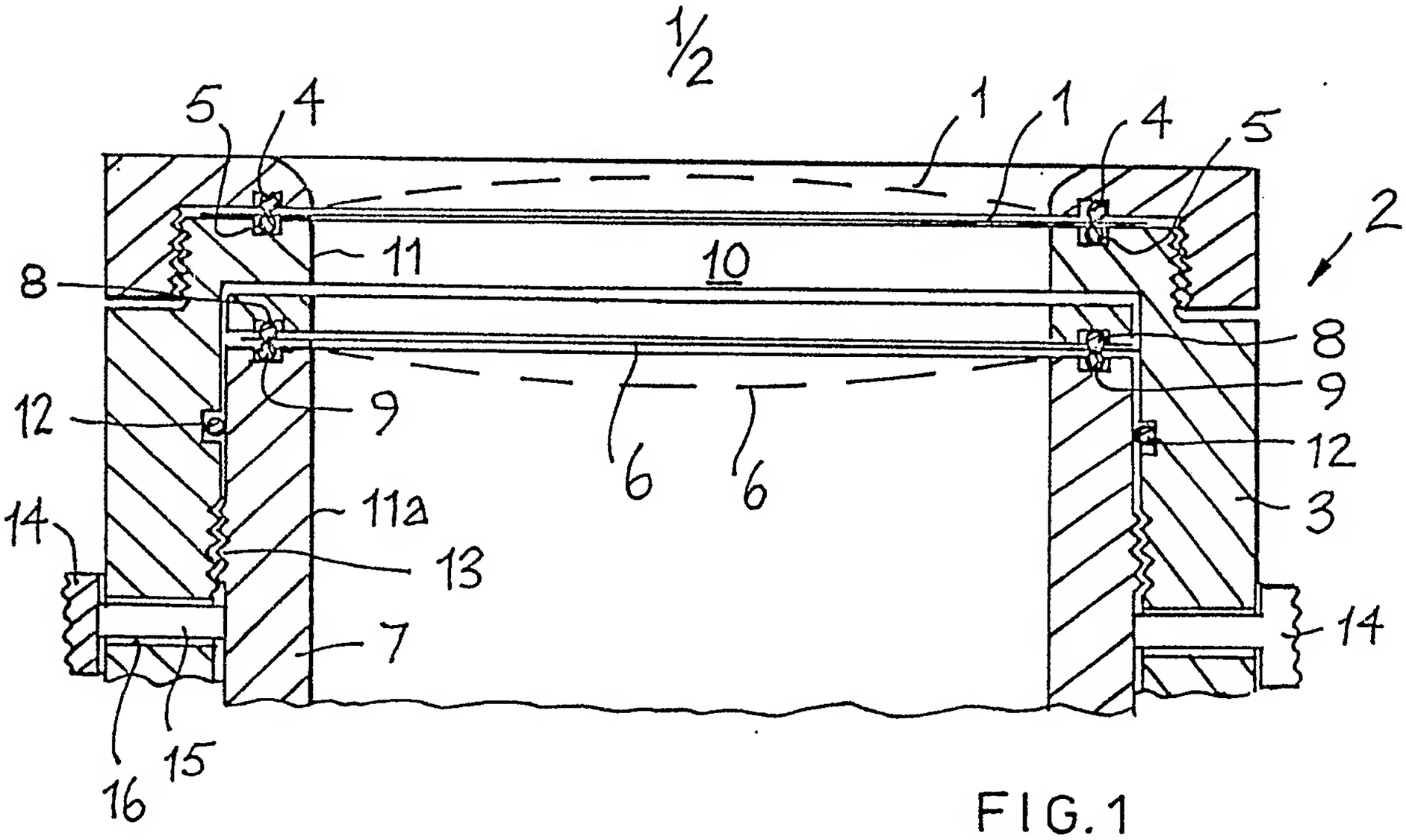
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FIG.1

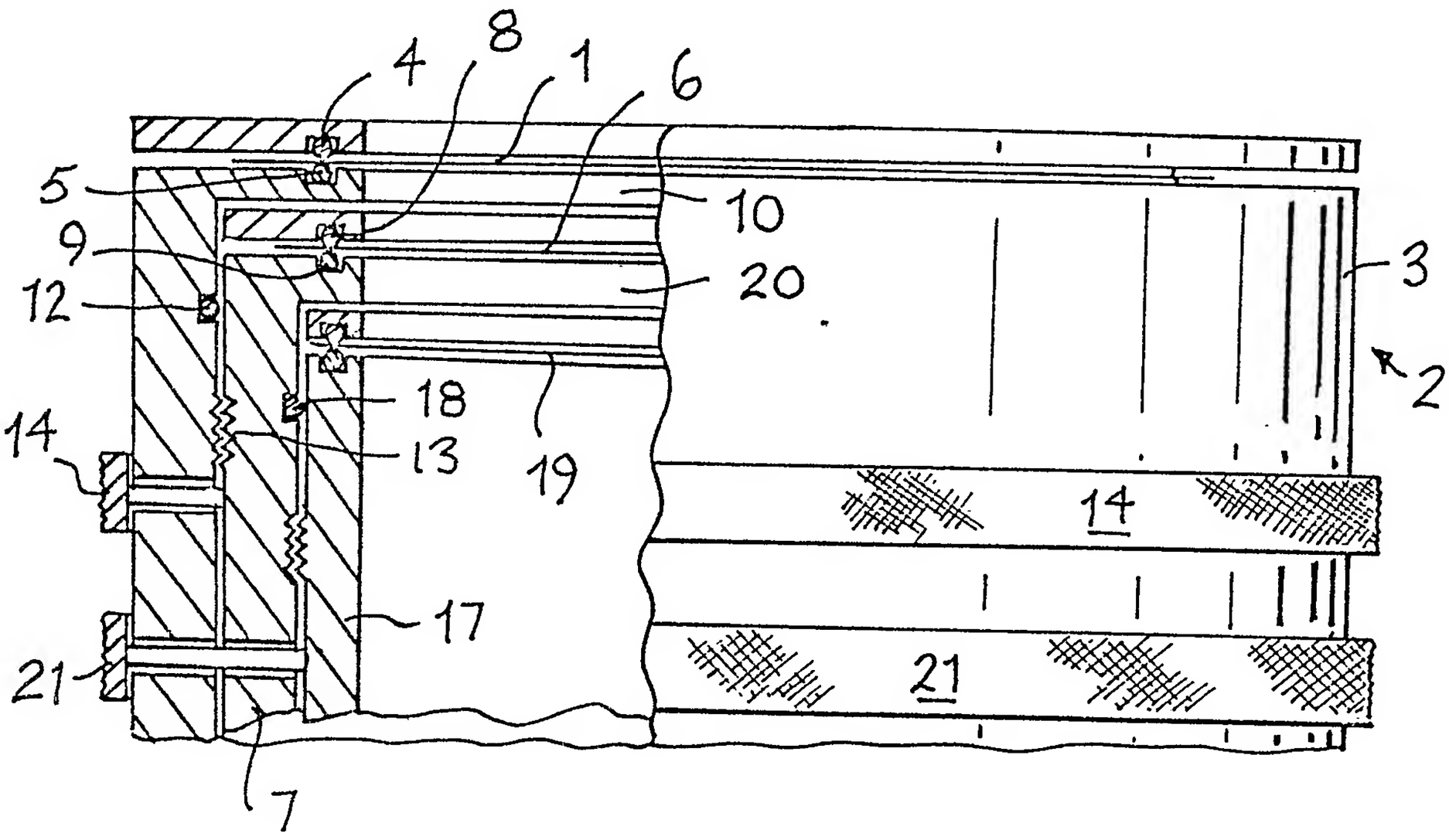
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FIG. 2

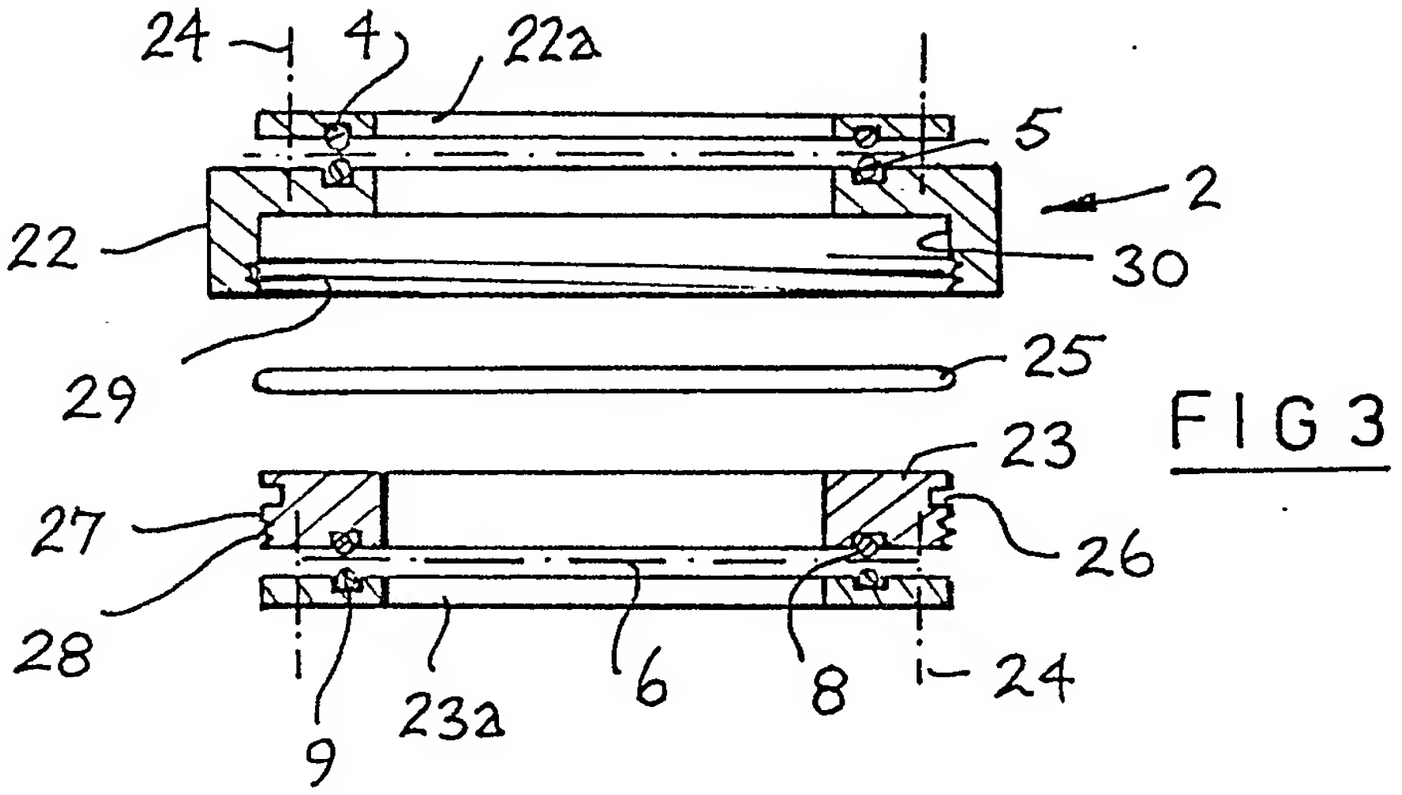

FIG 3

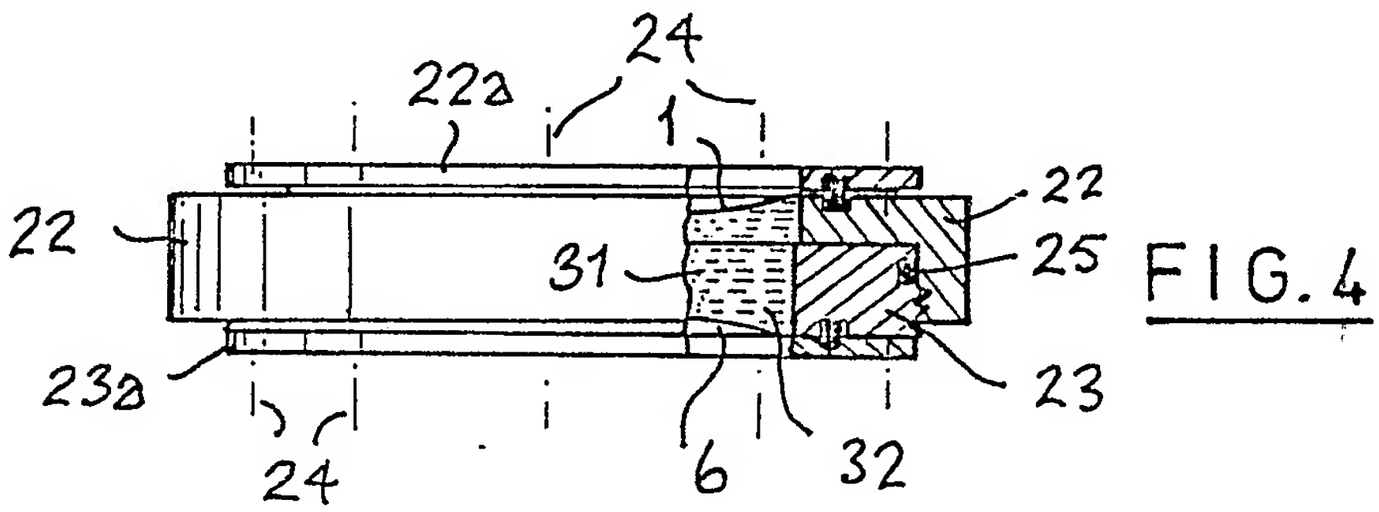

FIG. 4

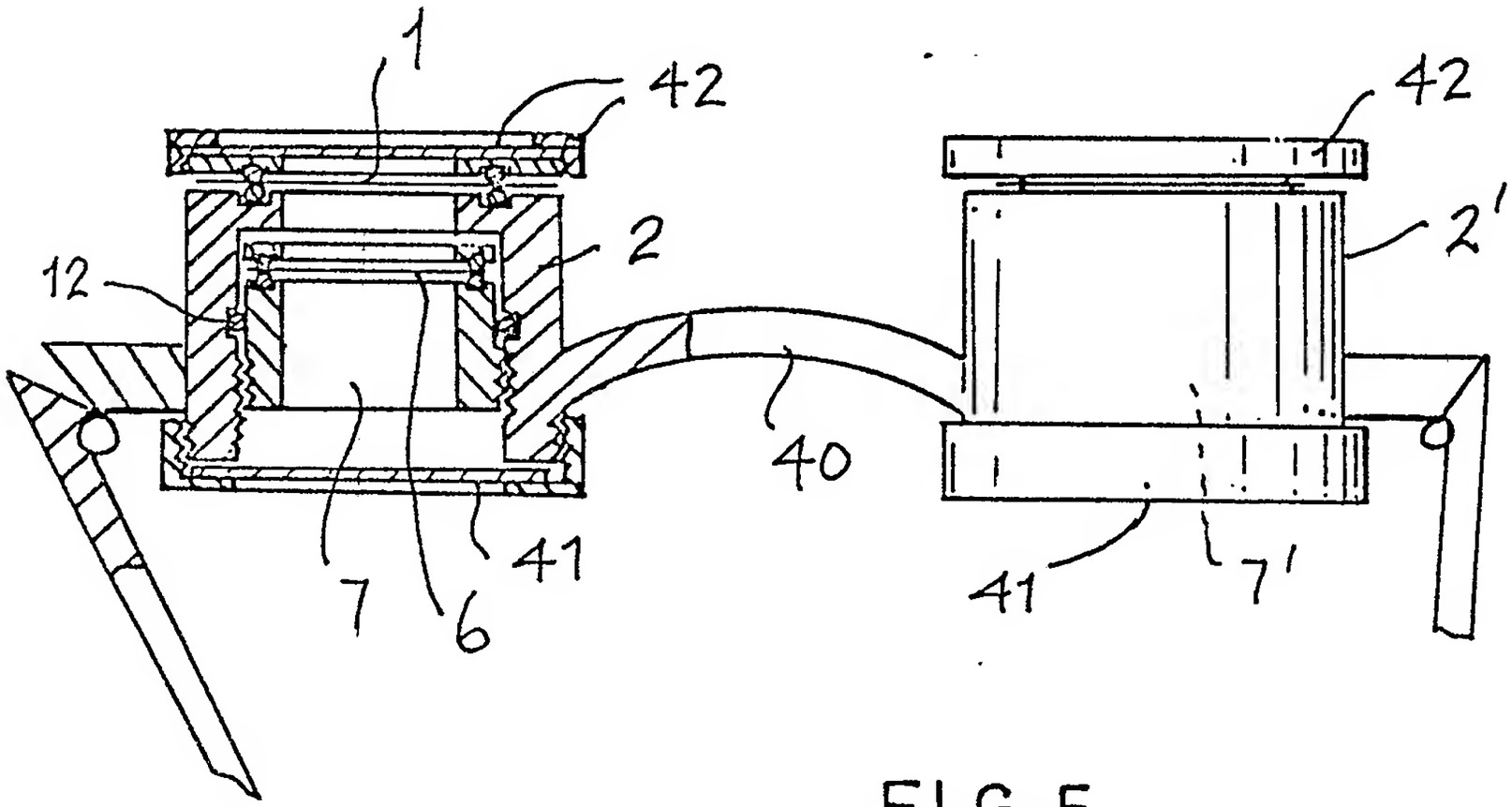

FIG. 5

SPECIFICATION

Liquid or semi-solid lens with intrinsic system for adjusting focal length

Technical field

This invention relates to a new design of liquid lens, the focal length of which can be altered by relative movement between component parts of the lens holder. The invention also relates to an adjustable focus mirror.

Background of the invention

A lens is an object, usually made of glass, shaped so that it will transmit electromagnetic radiation coming from a source (the "object") and focus that radiation into an "image" at another location in a way that preserves the spatial distribution in the source. A lens is commonly made of one or more solid pieces of material, such as glass or plastics, transparent to the radiation to be passed through it.

A liquid lens is a radiation refracting element having at least one boundary surface defined by a flexible membrane delimiting a volume of liquid transparent to the transmitted radiation. In one simple embodiment, a liquid lens is a hollow flexible object having spaced-apart flexible membrane surfaces, which object is filled with a liquid of refractive index different from the gas(es) surrounding it, so that the shape it adopts depends on the positive or negative pressures of the liquid filling it. A liquid lens of adjustable shape will be referred to herein as a "lensat". The liquid filling the deformable hollow object is pressurised by a device such as a pump, or is supplied from a sealed reservoir which may be deformed by any suitable external agent so as to vary the pressure in the lensat, so as to produce a suitable part-spherical or other curved shape of one or both of the membrane surface(s) to give the lensat the property of functioning as a lens with an adjustable focal length. Although a lens of adjustable focal length would have advantages, providing a facility for adjusting focal length from an external reservoir may present difficulties.

By making the membrane surface significantly reflective to the radiation incident on it, a mirror is created, and the invention also extends to an improved flexible membrane mirror.

Statement of the invention

According to the present invention, an adjustable liquid lens or mirror comprises a chamber delimited by a flexible membrane surface, a first fluid medium filling the chamber which, in the case of a lens, has a different refractive index from that of a second fluid medium contacting the other side of the flexible membrane, and an annular support member for the flexible membrane comprising relatively movable first and second component parts, the first and second component parts of the support member being adjustably linked in a fluid-tight manner whereby the volume of the chamber is adjustable by moving one component part of the support member relative to the other in such wise as to vary the pressure in the first fluid medium and thereby to alter the shape of the said membrane surface. As the fluid medium, may be used a semi-solid or gelatinous substance such as gelatine.

In the case of an adjustable mirror, the first and second fluid media could be the same, since there need be no transmission of radiation through the first medium.

The component parts of the support member may be screw threaded together so that relative rotation of one in or on the other causes the required pressure change in a simple but well controlled manner.

In the case of a liquid lens having two spaced-apart flexible membrane surfaces delimiting the fluid-filled chamber, the relatively adjustable component parts of the membrane support member can be screw-threaded together over part of interengaging cylindrical surfaces with an O-ring interposed between said surfaces, said O-ring defining a part of the boundary surface of said chamber, whereby rotation of one support member part relative to the other changes the pressure of the fluid within the chamber and thus effects a change in shape of each flexible membrane surface.

Brief description of the drawings

The invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a purely schematic sectional side elevation of a first embodiment of liquid lens according to the invention,

Figure 2 is a view similar to Figure 1 but of a two cavity liquid lens,

Figure 3 shows a schematic exploded sectional side elevation of a third embodiment of liquid lens according to the invention,

Figure 4 shows a partly sectioned side view of the assembled liquid lens of Figure 3, and

Figure 5 shows, in schematic sectional view, a pair of spectacles with two liquid lenses according to the invention.

Description of preferred embodiments

Figure 1 (not drawn to scale) shows one embodiment of adjustable power lens. An anterior flexible transparent membrane 1 is held in an outer part 3 of an annular holder 2 between a pair of O-rings 4 and 5. This method of mounting a liquid lens membrane in a lens holder is described in our co-pending British Patent Application 8621290. A posterior membrane 6 is held in a similar manner in an inner part 7 of the holder 2 by a further pair of O-rings 8, 9. The cavity 10 defined in the bore 11 of the holder between the membranes 1 and 6 is filled with a suitable liquid such as water, alcohol, gelatine or glycerol, and an O-ring seal 12 prevents leakage of the filling liquid between the parts 3 and 7. The part 7 screws into the part 3 at 13. By screwing the holder part 7 towards or away from the holder part 3, the pressure in the cavity 10 can either be increased, causing the membranes 1, 6 to flex outwardly and the liquid lens to become more positive, or reduced, causing the liquid lens to become more negative.

The medium in contact with the upper surface of the membrane 1 and the lower surface of the membrane 6 would normally be air but it will be appreciated this need not be the case. The bore 11a could contain some other gas or even a liquid of different refractive index from that filling the cavity 10.

The means for turning part 7 relative to part 3 of the holder 2 to effect a lens power change can take many forms. It could, for example, be a knurled ring 14 surrounding part 3 and connected to part 7 via a rod 15 located in an arcuate slot 16 in the part 3. Displacement without rotation is also possible (e.g. with an external screw clamp).

Figure 2 shows a rather more complex liquid lens having two liquid lenses one above the other. Where appropriate the same reference numerals have been used in Figure 2 as were used in Figure 1 to designate similar integers. The compound adjustable membrane autofocus lensat shown in Figure 2 has a third housing part 17 screw-threaded into the part 7 with a separate O-ring seal 18.

The third part 17 supports an O-ring tensioned third membrane 19 which defines a second cavity 20 inside the bore 11a. The third part 17 can be axially adjusted relative to the second part 7 to adjust the pressure in the liquid filling the cavity 20. This adjustment could be by way of a ring 21 operating in a manner similar to that described above for the ring 14. Since membrane 6 is now common to the cavities 10 and 20 adjustment of the pressure in one will have an effect on the power of the liquid lens defined by the other. This may be of advantage, but if not, can readily be compensated for by appropriate readjustment of the other ring 14 or 21. Different liquids can be used in the two cavities 10 and 20.

Figures 3 and 4 illustrate a lensat of a relatively compact design. As with the previous designs there are two transparent membranes (e.g. 23 micron thickness type D "Mylar" (RTM) material) 1 and 6 (shown only in chain lines) tensioned between respective pairs of O-rings 4, 5 and 8, 9. The housing 2 comprises a pair of annular members 22 and 23 which when interengaged with the membranes in place define a fluid-tight chamber of variable volume. The O-rings 4, 5 are pressurised on either side of the membrane 1 by an annular fixing plate 22a and the O-rings 8, 9 are pressurised on either side of the membrane 6 by an annular fixing plate 23a. Both fixing plates are tightened in place to tension the respective "MYLAR" membrane by means of a ring of screws (only shown schematically at 24).

The annular members 22, 23 are sealed in fluid-tight manner by an O-ring 25 designed to be located in a groove 26 in a cylindrical outer surface 27 of the member 23. A part 28 of the surface 27 is screw-threaded to mesh with a threaded part 29 of a second cylindrical surface 30 forming part of the member 22. The size of the O-ring 25 and the dimensions of the groove 26 in which it is located are selected (in known manner) to obtain sufficient deformation of the O-ring to provide a good fluid-tight seal between the surfaces 27 and 30 but not so great a deformation as to make it difficult to occasion relative rotation between the members 22, 23 when the power of the lensat is to be adjusted. The chamber 31 created in the member 22 by the seal 25 and the membranes 1 and 6 could be filled with air-free distilled water 32, for example as shown in Figure 4.

Figure 4 shows the third embodiment of lensat fully assembled and arranged to provide a negative double-concave lens. The liquid 32 filling the chamber 31 between the membranes 1 and 6 is at sub-atmospheric pressure, the pressure being adjusted by screwing the member 23 into or out of the member 22. Screwing in will reduce the power of the negative lens and screwing out will increase the power of the lens.

It will be seen therefore that the lensat constructions shown in Figures 1 to 4 each includes a piston-type arrangement in which one housing member moves as a sealed piston within the other to provide a "pumpless" lensat.

In each of the lensat designs illustrated one of the membranes may be replaced by a substantially rigid solid fluid-tight transparent member which may or may not have a power different from unity.

A telephoto lens is a system of lenses designed to allow a camera to photograph a magnified image of distant objects. A zoom lens is a system of lenses which can be adjusted by altering the physical arrangement of the lens components therein so as to alter the overall focal length and field of view to give it telescopic or near-field properties. Autofocus lenses of the kind described above may be used in place of solid lenses in a telephoto or zoom lens, telescope, binoculars, microscope, camera, or other optical device. They may be used in combination with fixed lenses. Thus a zoom lens can be constructed of two adjustable membrane autofocus lensats in sequence, one having a negative and the other a positive power. The relative positions of the lenses do not require to be altered in order to change the focal length of the combination. This can be done by rotating the inner and outer part of the holder of one or the other of the autofocus lensats.

If the anterior surface of a liquid lens (say membrane 1 in Figure 1) is covered with a reflective coating, this produces a flexible membrane mirror. By displacing the inner part 7 of the holder 2 in Figure 1, the focus of the membrane mirror 1 can be altered. A mirror of this construction can be considered to be an autofocus membrane mirror.

A pair of spectacles is a device consisting of two lenses in a frame that allows the lenses to be worn before the eyes so as to correct errors of refraction or supplement deficient accommodation. Spectacles are traditionally made with solid lenses. These have the disadvantage that the focal length is restricted (in the case of a bifocal lens to two values) and is not adjustable on demand. Figure 5 illustrates one possible design for spectacles in which the solid lenses have been replaced by autofocus lensats. The frame (shown at 40 in Figure 5) incorporates two holders 2, 2'. By rotating the inner parts 7 and 7' in the left and right lensats, the focus of each lensat can be adjusted over a continuous range of values to suit the eye of the wearer for an object of regard at a given distance. The frame 40 may attach directly to

the part 7, in which case the outer part 2 may fit on to part 7 by a screw- or slide-fitting.

Discs 41 and 42 of transparent unbreakable plastic or glass may be fixed to the rear and front of each lensat holder so as to protect the flexible membranes 1 and 6 from dirt and damage. The discs 41 and 42 may be clip-on or otherwise removable attachments (e.g. bayonet or screw mounted), or they could be permanently attached. The discs 41 and 42 may themselves be solid lenses that provide a basic correction to vision which can be further adjusted by altering the focal lengths of the lensats. They may be planar, or they may have a cylindrical surface to allow for the correction of astigmatism. The surfaces of one or both discs may be so shaped as to correct for any aberrations associated with the liquid lens over a range of focal lengths. They may be transparent or tinted (e.g. light-intensity colour-controlled), so allowing the spectacles to be used as sunglasses of variable focus and variable tint. The spectacles of Figure 5 use lensats of the kind shown in Figure 1 but other designs are clearly possible.

This invention thus relates to novel types of liquid or semi-solid lenses which allow the focus of the lens to be altered directly by manipulating the relative positions of components of the holders of the lenses. Such lenses may be constructed of at least one membrane and preferably a membrane held between O-rings. Direct variation in the volume of the chamber delimited by the membrane(s) may be used to alter the internal pressure in the lens and so its focal length, giving a lens of directly adjustable focus. Such liquid lenses may be combined to produce compound lenses with both components separately adjustable or adjustable in some linked manner and they may be used to construct telescopes, zoom lenses, spectacles, cameras and a wide range of other optical devices.

If the means used for adjusting the pressure exerted on the membrane is calibrated in some way, the lensats described above can be used by an opthalmologist in determining the refraction of a patient or by an optician in determining what power of spherical lens needs to be prescribed for each eye of a patient.

The calibration is conveniently arranged to read directly in dioptres but it is possible to have some other graduated scale and a reference chart to relate the scale readings to the appropriate lens power. Thus the arrangements described could be used to provide the calibration by marking a scale on one member and providing a pointer, line or other reference mark on the other, which moves along the scale as the lens power is changed.

It is envisaged that one or a few small disc-shaped lensats such as that shown in Figure 3 could be used as replacement for the many fixed focus lenses normally used in prescribing spectacles and for other opthalmic purposes.

Further, if the focal length adjustment, in say the spectacles of Figure 5, is made sufficiently easy to operate and is manually accessible to a patient viewing through the lensat, the patient can adjust the focal power to optimise the sharpness of focus he/she is experiencing during a test, thereby facilitating the selection of the correct lens power required to compensate for vision defects.

In case ageing of the membrane produces loss of calibration accuracy, a re-adjustment facility can be provided on each lensat to enable periodic re-calibration. For example, this could be a separate pre-settable pressure-adjusting means, or the pointer referred to above could be capable of having its position of attachment to the housing adjusted.

A cylindrical lensat of adjustable focus can be produced by using membranes of graded thickness and such lensats can be used to correct astigmatic errors.

It is also possible to provide a lensat with an at least partial cylindrical lens by trapping the flexible membrane between confronting O-rings held in respective grooves that follow cylindrical surfaces. Thus, for example, the grooves accommodating O-rings 4 and 5 in Figure 1, rather than being coplanar as shown, can each lie on a cylindrical surface, the O-ring 4 (say) lying on a first cylindrical surface of a given radius and the O-ring 5 lying on a second cylindrical surface of the same or substantially the same radius. In a pluri-chamber lensat, cylindrical components can be added to more than one of the membranes and the axes of the two or more different cylindrical components of the lens surfaces need not be parallel. The surfaces followed by a confronting pair of O-rings need not be cylindrical if they are non-planar thus leaving open the possibility of fabricating complex lens surface contours for specific applications.

Although the tensioned regions of the membranes disclosed thus far are circular in plan, there is no need for this to be the case and the invention should be seen to include non-circular tensioned membrane regions. In some applications a rectangular membrane could be used and such a membrane shape can be achieved either by using a rectangular O-ring (e.g. made from lengths of circular section elastomeric rod mitre-joined at the corners) or by using a pair of circumscribing circular O-rings to form the primary seal of the cavity to the membrane and to tension the membrane but contacting the tensioned membrane within the bore of the O-rings by a rectangular frame that defines the optical boundary of the lensat.

CLAIMS

1. An adjustable liquid lens or mirror comprising a chamber delimited by a flexible membrane surface, a first fluid medium filling the chamber which, in the case of a lens, has a different refractive index from that of a second fluid medium contacting the other side of the flexible membrane, and an annular support member for the flexible membrane comprising relatively movable first and second component parts, the first and second component parts of the support member being adjustably linked in a fluid-tight manner whereby the volume of the chamber is adjustable by moving one component part of the support member relative to the other in such wise as to vary the pressure in the first fluid

medium and thereby to alter the shape of the said membrane surface.

2. A lens or mirror as claimed in claim 1, in which the first fluid medium is a transparent liquid.

3. A lens or mirror as claimed in claim 1, in which the first fluid medium is a semi-solid or gelatinous substance.

4. A lens or mirror as claimed in any preceding claim, in which the component parts of the support member are screw-threaded together so that relative rotation of one in or on the other causes the required pressure change in the first fluid medium.

5. A liquid lens as claimed in claim 1, 2 or 3, having two spaced-apart flexible membrane surfaces delimiting the fluid-filled chamber, the relatively adjustable component parts of the membrane support member being screw-threaded together over part of interengaging cylindrical surfaces with an O-ring interposed between said surfaces, said O-ring defining a part of the boundary surface of said chamber, whereby rotation of one support member part relative to the other changes the pressure of the first fluid within the chamber and thus effects a change in shape of each flexible membrane surface.

6. A liquid lens as claimed in claim 5, in which there are three flexible membranes defining two adjacent fluid-filling chambers formed in a housing having outer, middle and inner components, one of said chambers being defined in part by a seal formed between the outer and middle components and the other of said chambers being defined in part by a seal formed between the middle and inner components.

7. A liquid lens as claimed in claim 6, in which relative rotation is possible between the middle and outer components to vary the volume of the said one chamber and relative rotation is possible between the middle and inner components to vary the volume of the said other chamber.

8. A lens or mirror as claimed in claim 1, in which the first and second component parts exhibit closely adjacent cylindrical surfaces between which an O-ring seal is located.

9. A lens or mirror as claimed in claim 8, in which the adjacent cylindrical surfaces each extend away from respective intermeshing screw-threaded parts.

10. A lens or mirror as claimed in any preceding claim, in which each membrane is held in place in its housing part between a compressed pair of O-rings.

11. A pair of spectacles comprising two liquid lenses as claimed in any preceding claim mounted in a frame.

12. The combination of a lens as claimed in any preceding claim with a further lens to provide a telephoto or zoom lens, a telescope, binoculars, a microscope or a camera.

13. A liquid lens substantially as hereinbefore described with reference to, and as illustrated in Figure 1, Figure 2, Figures 3 and 4 or Figure 5 of the accompanying drawings.

Amendments to the claims have been filed, and have the following effect:-

*(a) Claims 1, 5, 6, 8, 9, 10 and 12 above have been deleted or textually amended.

*(b) New or textually amended claims have been filed as follows:-

*(c) Claims 11 and 13 above have been re-numbered as 9 and 11 and their appendancies corrected.

1. An adjustable liquid lens or mirror comprising a chamber delimited by a flexible membrane surface, a first fluid medium filling the chamber which, in the case of a lens, has a different refractive index from that of a second fluid medium contacting the other side of the flexible membrane, and an annular support member for the flexible membrane comprising relatively movable first and second component parts, the first and second component parts of the support member exhibiting closely adjacent cylindrical surfaces between which an O-ring seal is located and being adjustably linked in a fluid-tight manner whereby the volume of the chamber is adjustable by moving one component part of the support member relative to the other in such wise as to vary the pressure in the first fluid medium and thereby to alter the shape of the said membrane surface, the membrane defining said membrane surface being held in place between a compressed pair of O-rings.

5. A liquid lens as claimed in claim 1, 2 or 3, having two spaced-apart flexible membrane surfaces delimiting the fluid-filled chamber, the relatively adjustable component parts of the membrane support member being screw-threaded together over part of interengaging cylindrical surfaces with an O-ring interposed between said surfaces, said O-ring defining a part of the boundary surface of said chamber, whereby rotation of one support member part relative to the other changes the pressure of the first fluid within the chamber and thus effects a change in shape of each flexible membrane surface, each membrane defining a membrane surface being held in place in its respective support member between a compressed pair of O-rings.

6. A liquid lens as claimed in claim 5, in which there are three flexible membranes defining two adjacent fluid-filled chambers formed in a housing having outer, middle and inner components, one of said chambers being defined in part by a seal formed between the outer and middle components and the other of said chambers being defined in part by a seal formed between the middle and inner components, the third membrane also being held in place between a compressed pair of O-rings.

8. A lens or mirror as claimed in claim 1, in which the adjacent cylindrical surfaces each extend away from respective intermeshing screw-threaded parts.

10. The combination of a lens as claimed in any preceding claim with a further lens to provide a telephoto or zoom lens, a telescope, binoculars, a microscope or a camera.

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